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INDICATORS OF CANADIAN RESEARCH OUTPUT, 1984

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INTRODUCTION

This working paper presents a comparative analysis of national research performance using bibliometric statistics.(1) Two indicator series are presented: research output (measured in terms of published articles), and research impact (measured in terms of citations to published articles). The discussion focuses on Canada's performance relative to the activities of five other industrial countries; the U.S.A., the U.K., West Germany, France and Japan.

The data source is the "Science Literature Indicators Data Bank", compiled by Computer Horizons, Inc. (CHI) on behalf of the National Science Foundation for use in the **Science Indicators** report series. The procedures employ data from the Science Citation Index (SCI) database of the Institute for Scientific Information.(2) This data bank contains the most readily accessible data on national publication and citation indicators. Statistics are available on an annual basis from 1973-1984, and for eight broad fields of science: Clinical Medicine, Chemistry, Biomedical Research, Physics, Engineering and Technology, Biology, Earth and Space Science and Mathematics. For the majority of the indicators, a seven country set has been identified (the six above plus the U.S.S.R.: authors from these countries account for roughly three-quarters of all papers recorded in the SCI database for the period under review). The publication and citation counts are available for 197 countries and geopolitical regions. In addition, the publication data are available for 100 subfields.(See Table 9)

The following section presents an overview of the general health of Canada's research performance: possible trends and patterns for the defined scientific fields are examined along with international comparisons of Canada's activities. Next, some general remarks on bibliometric studies and on the Science Literature Indicators Data Bank are provided.

It is recognized that, one, there are limitations with this bibliometric indicator series and methodology: it is hoped their use here will further the development of appropriate indicators for Canada. Secondly, while newer developed methodologies and indicators focus on research performance at more disaggregated units of study than provided by this series (e.g., a research specialty or specific organization), it can and has served as preliminary data to the more comprehensive discussions.

For a description of the theory for the use of bibliometrics as an indicator of scientific research activities as well as other examples of bibliometric indicators, see **An Indicator of Excellence in Canadian Science,** Catalogue No. 88-501E, 1985. A simplification of this report was published as **An Indicator of Excellence in Canadian Science: Summary Report**, Catalogue No. 88-507E, 1984.

CANADIAN RESEARCH PERFORMANCE

In 1973, Canadian authors were responsible for about four percent of the world's scientific papers as represented by the Science Citation Index, and our share of world activity has remained fairly constant since then. Chart 1 presents national shares of the world's publication output for the six selected countries in 1973 and 1984: the number of published papers with a Canadian author totalled 11,900 for 1973 and 12,300 for 1984. The average annual percent change over the twelve-year period was 0.3%. As a benchmark for comparisons with activities elsewhere, we note that the average annual percent change for total world output (the number of papers being published by the journals monitored), was 0.5%.

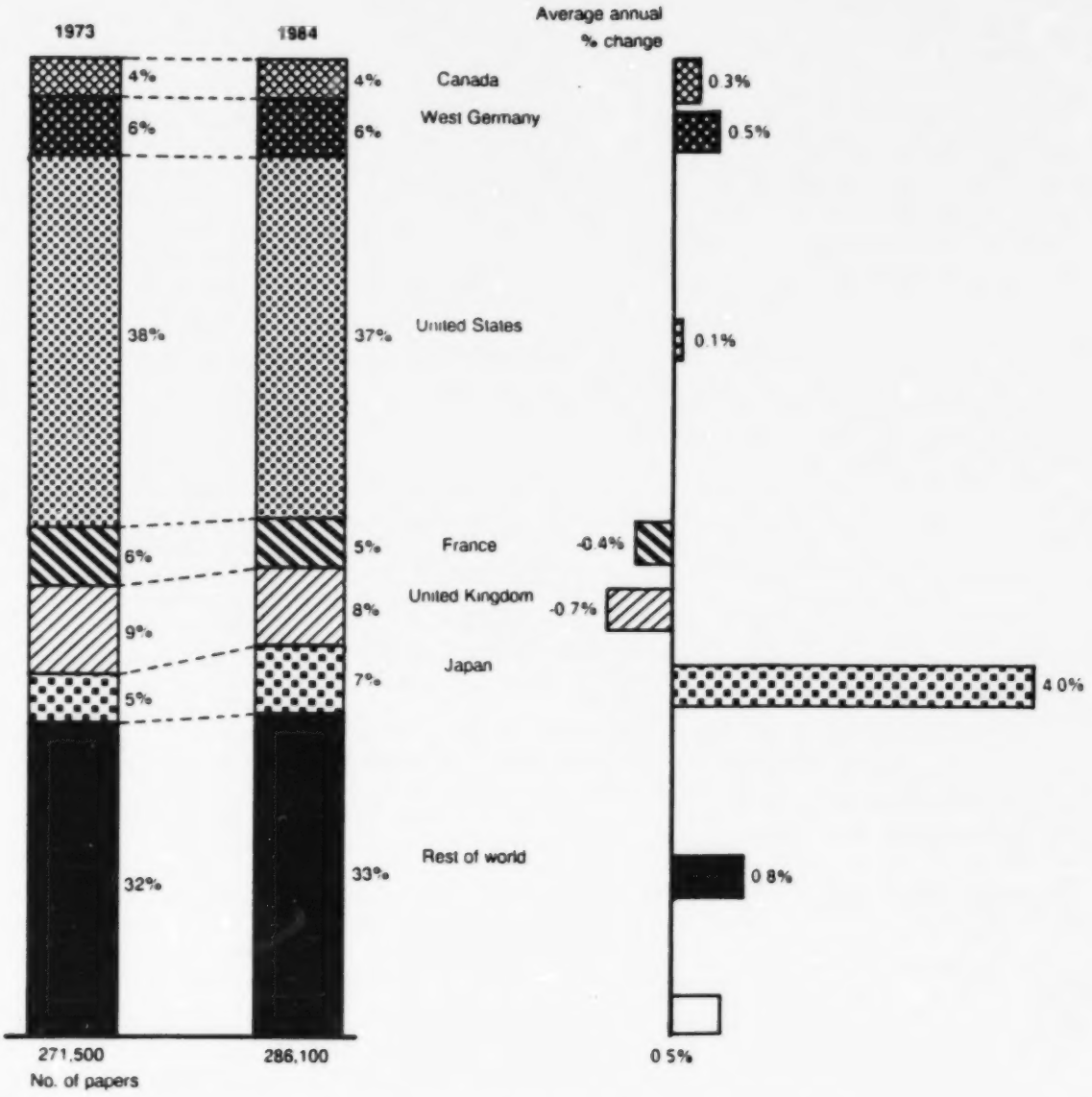
The most noticable change in national shares concerns Japan. Japan's relative share of world activity increased from 5.3% in 1973 to 7.6% in 1984; in order to do this, the volume of Japanese-authored papers had to increase by more than 50%. Martin and Irvine in a recent study on national research performance for the U.K., examined whether this rising Japanese share of world output was attributable to a genuine increase in output, a change in Japanese researchers' publication policies or a change in the database's monitoring policy. They found that '...the proportion of Japanese papers that is published in English-language journals has indeed increased, but there has been an increase (albeit a rather small one) in the output of Japanese-language papers'. They concluded that '...the increasing Japanese share of the database represents a real increase in output rather than a changed strategy for publishing a constant number of papers'.(3)

The U.S.A. is the predominant source of the world's research output as represented here. Close to half of all papers in the SCI database fall within the fields of clinical medicine and biomedical research and therefore help to support this large U.S. share. SCI's concentration of literature coverage in these two research areas is largely due to its original purpose for construction: a citation index to genetics literature.

Over the study period (1973-1984) the proportion of papers by U.S. authors has tended to fall slightly. As shown in Appendix Table 1, the U.S.A. experienced declines in its world share for four of the eight fields. Japan, on the other hand, showed extensive increases in its publication output and share of international activity for seven of the eight fields (and maintained its level of activity in the eighth). Table 1 shows the contribution by authors of the selected countries to the world's research papers for all years combined and the average annual percent change in output, for each of the eight fields. The fields are listed in terms of their representative proportion of the total number of published papers in the database. Clinical medicine, the largest field in the database, represented 29% of all papers published between 1973 and 1984. The smallest fields were earth and space science (4%) and mathematics (3%).

Chart-1

Country Shares of the World's Research Papers



Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987

Table 1. World's Research Papers, by Field, 1973-1984

Field	U.S.A.	U.K.	Germany	France	Japan	Canada	Rest of world		World
							U.S.S.R.	Other	
	percent share								
Clinical medicine	43	10	6	6	5	4	3	25	100
Chemistry	22	7	7	6	10	3	16	29	100
Biomedical research	40	9	6	6	6	4	6	24	100
Physics	31	7	7	6	8	3	16	23	100
Engineering and technology ..	41	10	8	3	7	5	9	18	100
Biology	44	10	4	4	6	8	2	23	100
Earth and space science	45	9	4	5	2	6	10	20	100
Mathematics	42	7	8	8	5	5	4	22	100
	average annual percent change								
Clinical medicine	1.2	0.8	-0.4	0.6	6.9	2.4	-0.6	1.6	1.3
Chemistry	-0.6	-2.1	1.1	-2.1	2.2	-1.7	-0.4	1.6	0.2
Biomedical research	1.2	-0.7	1.1	-1.8	6.2	1.0	0.5	0.8	0.9
Physics	0.1	-1.5	3.9	2.7	3.9	-0.2	-0.3	2.9	1.1
Engineering and technology ..	-1.8	-4.0	-1.7	-1.3	3.2	-1.3	-5.6	0.6	-1.7
Biology	-0.1	1.5	0.7	-0.4	3.2	1.3	1.1	1.4	0.7
Earth and space science	0.1	1.0	3.5	0.2	3.2	1.6	-0.1	1.8	0.6
Mathematics	-4.9	-3.3	-0.4	-1.1	1.8	-4.7	0.7	0.6	-2.6

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

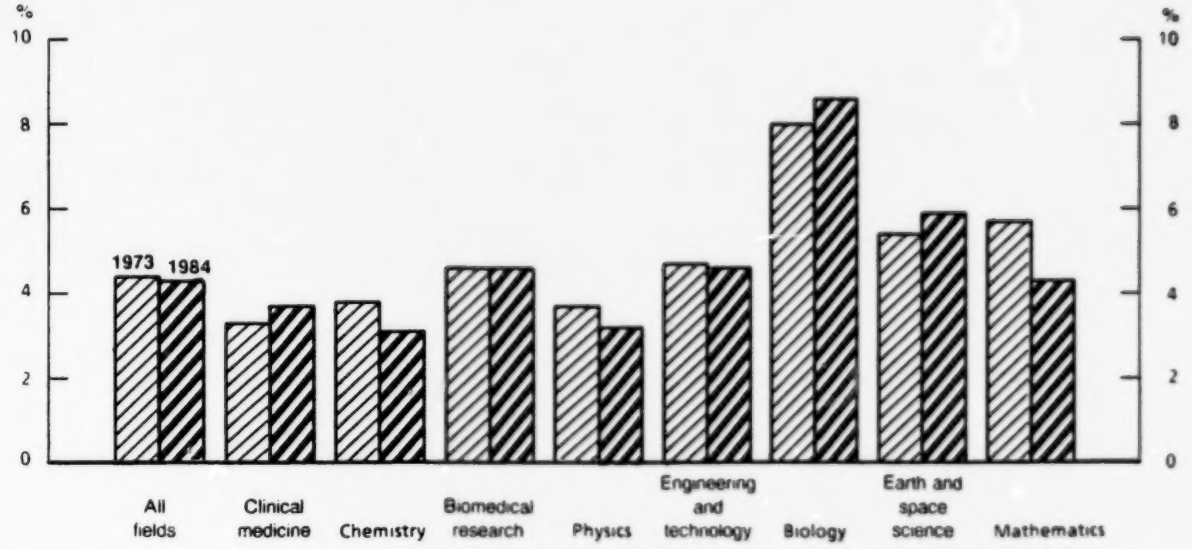
From the many quantitative and qualitative studies of scientific literature it has been shown that every discipline has its own inherent communication characteristics. Each seems to have a particular method of communicating research findings which is used more frequently than others; hence productivity levels may appear to vary substantially among disciplines. For example, in the technical sciences, oral communications (e.g., congresses) tend to be used more than written communications such as journal papers. Researchers in the area of plasma physics are known to send their results directly to interested collegues rather than taking the longer route of publishing them in journals.(4) As well, editorial practices such as page limitations (which also affect the number of references in a paper) or costs (which presumably have a limiting effect on the number of papers published) vary considerably among disciplines.(5)

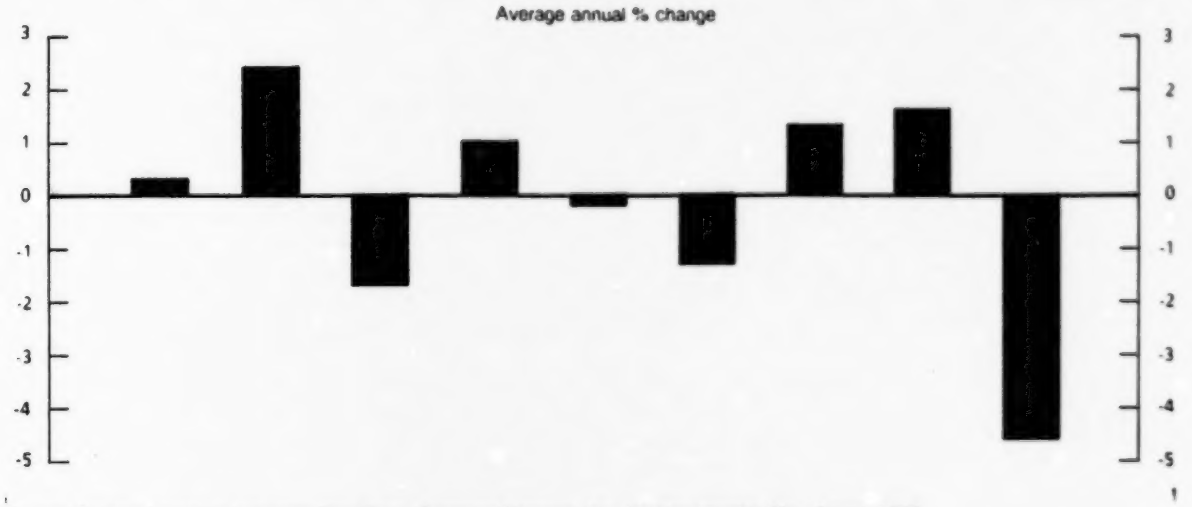
Disciplinary characteristics, like those above, will strongly influence bibliometric analyses, and must be kept in mind when examining field activity. Ideally, we should concentrate on individual disciplines and present comparative analyses of the output of the study unit (in this case, a country) in relation to the activity of other units (i.e., countries).

Chart 2 presents Canada's share of world output by field for 1973 and 1984, along with corresponding changes in publication levels. For the latter part of this study's timeframe, Canadian authors were apparently contributing relatively less in three fields and relatively more in three, compared to publication output levels at the start.

Chart-2

Canada's Share of the World's Research Papers, by Field





Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987

The largest increase in the number of papers published by Canadian authors over the 12-year span was in the field of clinical medicine (23% between 1973 and 1984). However, because publications from the rest of the world rose by a similar amount (15%), our share of international activity increased only slightly. The national publication counts series presented here are available by subfield (see Table 2 below and Appendix Table 2).

The clinical medicine field is composed of 34 subfields or specialties. Canadian authors contributed papers in all of them, accounting for 3.6% of the world's output for this field during the 1973-1984 period. As shown in Table 2, our research publication activity in each of the five subfields presented (addictive diseases, veterinary medicine, anesthesiology, respiratory system and allergy) was relatively higher than this overall value. For 1984 alone, our largest contribution was in the general category of 'miscellaneous clinical medicine'; with only 30 papers, Canadian authors accounted for 9.6% of the world's total output for this subfield. Details of Canadian activity for each of the 100 subfields for 1984 are found in Appendix Table 2.

Based on our share of world research output in four of the eight fields, Table 2 attempts to highlight areas of strength in Canada's international research performance. Data are presented for subfields in which Canadian authors were responsible for relatively more than our share of the world's publication output for the 'field in total' for the 1973-1984 period combined.

Table 2. Canada's Share of the World's Research Papers for Selected Subfields, 1973-1984

Field and subfield	Number of research papers	Percent of world share
	rounded to nearest 100	
Clinical medicine	**34,300**	**3.6**
Addictive diseases	300	9.7
Veterinary medicine	2,000	6.7
Anesthesiology	800	6.5
Respiratory system	700	6.2
Allergy	300	5.1
Biomedical research	**22,600**	**4.3**
Physiology	3,200	9.2
Anatomy and morphology	500	6.2
Biomedical engineering	600	6.1
Microbiology	2,200	5.9
Engineering and technology	**13,200**	**4.5**
Chemical engineering	2,100	6.9
Materials science	1,900	6.6
Operations research and management science	300	5.5

Table 2 concluded

Biology	**24,100**	**8.3**
General zoology	2,900	26.1
Entomology	2,400	12.1
Dairy and animal science	2,500	12.0
Marine biology and hydrobiology .	2,400	11.9

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Canada was responsible for 3.4% of the world's research papers published in chemistry. As shown in Chart 2, our world representation declined significantly from 3.8% in 1973 to 3.1% in 1984 and was accompanied by a drop of 22% in the number of papers produced in these two years (average annual percent change -1.7%). The U.K. and France both experienced similar (larger) declines in activity for this field; the growing volume of papers by Japanese authors (and to some extent West German authors) is notable. For 1984, Canadian activity at the subfield level showed contributions to each of the seven chemistry specialties; our share of the world's publication output ranged from 1.5% in applied chemistry to 3.8% in general chemistry (see Appendix Table 2).

Biomedical research includes such fast growing disciplines as genetics, physiology, biomedical engineering, cell biology and microbiology. The U.S.A. tends to dominate this field (40% of world share), however, there was a substantial increase in Japan's relative position (7% for 1984 versus 4% for 1973). Again, France and the U.K. showed substantial decreases in their relative shares. Canadian authors were particularly active in the subfield of physiology. Activities in microbiology and anatomy, biomedical engineering, and morphology are also noted.

As shown in Chart 2, Canada's publication level decreased by 4% over the 1973-1984 period for physics; consequently our share of world activity declined (from 3.7% to 3.2%). Comparing publication activities in the first part of the period under review (1973-1976) to following years (1977-1980 and 1981-1984) we note Canada's rate of decline in world share was surpassed only by that of the U.K. Japan, the 'Rest of world' and West Germany all made substantial increases in their contributions to this field.

Just under 5% of the international publication activities covered by engineering and technology related journals were attributed to Canadian authors. We had a fairly small representation in most of the 13 subfields; however, as shown in Table 2, in 3 subfields our participation levels were relatively higher than for the field in total. At the field level, attention is drawn again to the expanding activities of France and Japan. The U.S.A. is holding on to its world position: this appears to be due mainly to the overall decrease in the world's publication output for the field over the twelve years (average annual percent change -1.7%).

The greatest Canadian share of world research output activity was in biology, representing 8.3% of the total publication output. The number of Canadian papers produced increased 14% over the 1973-1984 period (average annual percent change 1.3%). Areas of strength include general zoology, entomology, dairy and animal science and marine biology and hydrobiology (see Table 2).

Earth and space science is the third field in which Canadian production levels increased over the period (by 15% between 1973 and 1984), resulting in our share of world activity representing 5.9% of total output for this field in 1984. Of particular note for this year, is our international participation rate for the earth and planetary science specialty (7.7% or 355 research papers as shown in Appendix Table 2).

The mathematics field is the smallest of the fields in the database and the most dramatic in terms of changes in total world output and country publication levels between 1973 and 1984. Canada's share of international literature fell by nearly one-and-a-half percentage points over this twelve-year span and the actual number of Canadian-authored papers for 1984 totalled little more than half the count for 1973. The remaining countries in the group of six, excluding Japan, also experienced significant declines in activity. U.S. contributions dropped from 48% of world share in 1973 to 39% in 1984 - an effect of the large fall (38%) in published output between the two years.

Data on co-authored papers can provide useful information about a country's involvement in the international research community. As discussed in **Science Indicators - 1982**, co-authorship is fairly common among researchers of the same organization and in some fields where team efforts are more prevalent. For example, much of the advanced physics work is now conducted at large and unique facilities that are too expensive to duplicate in each country, and which have numerous visiting foreign researchers. The earth and space science field is also considered to be global in nature, necessitating collaborative research between different countries. Finally, mathematics is not a facility-bound field, making collaborative efforts possible through the exchange of papers and ideas.(6)

In 1984, a total of 6,200 co-authored papers having at least one Canadian address were identified in the SCI database. Fifty-five percent of these were combined works from within Canada; the other 45% involved a foreign author. As presented in Table 3, the distribution of Canadian co-authorship linkages among countries shows a slight change in activity over the years under review. There was a substantial increase in the actual number of co-authored papers with foreign countries; and the proportions of co-authorships with foreign countries versus within Canada shifted from a 39%-61% split for the earlier years (i.e., 1973-1976) to a 44%-56% for the latter (1981-1984). Co-authorships with U.S. residents decreased in 'relative share' terms from 53% for 1973-1976 to 48% for 1981-1984. Small increases in Canadian co-authorship activity with French researchers and with those included in 'Rest of world' are noted.

Table 3. International Co-authorship Linkages with Canada

Country	1973-1976		1977-1980		1981-1984	
	average number	percent	average number	percent	average number	percent
United States	792	53	936	50	1,224	48
United Kingdom	200	13	232	12	279	11
West Germany	49	3	69	4	109	4
France	84	6	141	7	202	8
Japan	26	2	45	2	76	3
Rest of world	348	23	460	24	666	26

Table 3 concluded

Total co-authorships with foreign countries .	1,498	39	1,884	41	2,556	44
Co-authorships within Canada	2,321	61	2,666	59	3,190	56

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Co-authorship data for each of the eight fields are presented in Appendix Table 3. Canadian co-authorships have increased in all fields over the study period, and, while the U.S.A. dominates our links with foreign countries, its relative share fell in four of the fields for this period. The field of mathematics has the greatest degree of international co-operation (i.e., about 89% of all co-authorships were with foreign authors), followed by physics (68%), earth and space science (63%) and chemistry (62%): clinical medicine appears to be largely nationally-based (27%).

As noted earlier, citation counts can be used as indicators of the impact of research findings on the international research community; their use is based on the argument that the most significant literature will be more frequently cited than routine literature. The reader is reminded of the numerous limitations in a bibliometric - citation analysis; citation practices differ among fields, citation practices within fields can change during a decade and the difference in reference practices of authors, are a few.(7)

The statistics which follow are based on citations made to papers published in three years: 1973, 1977 and 1981. The papers in 1973 have been cited over the years 1973-1984; those published in 1977 had been cited over the period 1977-1984; and those published in 1981, for 1981-1984. Unfortunately, the national citation indicators series are not available from this data bank at the subfield level.(8) Little analysis can be done at the field level due to the differing characteristics of the many subfields which comprise a field as well as the varying Canadian participation in these subfields.

To examine the impact of a country's research papers, CHI has developed the relative citation ratio (RCR). This measure is defined as the ratio of a country's national share of citations for a given 'citing source' (for a given field) to its share of the world's published papers (for a given field). The 'citing source' can refer to a specific country, the world or the world excluding the country under examination. A RCR value of more than one indicates relatively more references are made to a country's research papers by the 'citing source' than would be expected from the number of published papers in the database attributed to the country under review. Conversely, a value of less than one indicates a lower citation rate and, presumably, less impact.

Table 4 presents RCR's of the world and international use of Canadian-authored papers. World citations to Canada include citations made to Canadian-authored research papers by foreign-authored and Canadian-authored papers: international citations to Canada exclude those citations made by Canadian research papers. The RCR for the world use of Canadian-authored research is defined as follows:

for a given field and year,

$$RCR = \frac{\text{no. of citations to Canadian-authored papers in the database} \,/\, \text{total no. of citations in the database}}{\text{no. of Canadian-authored papers in the database} \,/\, \text{total no. of research papers in the database}}$$

For the international use of Canadian-authored research it is:

for a given field and year,

$$RCR = \frac{\text{no. of citations by world to Canadian-authored papers} \,/\, \text{no. of citations by world to world-authored papers} \;-\; \text{no. of citations by Canada to Canadian-authored papers} \,/\, \text{no. of citations by Canada to world-authored papers}}{\text{no. of Canadian-authored papers in the database} \,/\, \text{no. of research papers in the database}}$$

From Table 4 it appears that, generally, more recently published papers have less of an impact than earlier papers. As well, there is a tendency for Canada to cite its fellow national researchers. These two points are again illustrated in Appendix Table 4; this time for the U.S. scientific community. In general, citations to Canadian research results appear to be somewhat low with the exception of activities in chemistry.

Table 4. World Use of Canadian-Authored Papers, by Field

Field	Year(1) 1973	1977	1981
	percent share		
Canada's share of world citations(2):			
Clinical medicine	3.57	3.76	3.62
Biomedical research	3.83	3.50	3.65
Biology	9.15	8.47	7.70
Chemistry	5.92	5.50	4.32
Physics	3.67	3.27	2.91
Earth and space science	5.55	4.82	3.75
Engineering and technology .	5.92	5.09	4.36
Mathematics	4.24	4.41	4.40
Canada's share of international citations(2):			
Clinical medicine	2.99	3.00	2.69
Biomedical research	3.07	2.62	2.46
Biology	6.45	5.17	4.02
Chemistry	4.58	3.99	2.81
Physics	2.88	2.41	1.90
Earth and space science	4.19	3.37	2.57
Engineering and technology .	4.47	3.59	2.89
Mathematics	3.17	3.11	2.99

Table 4 concluded

Canada's share of world research papers:			
Clinical medicine	3.33	3.65	3.58
Biomedical research	4.56	4.30	4.32
Biology	8.04	8.60	7.66
Chemistry	3.84	3.69	3.21
Physics	3.72	3.47	3.00
Earth and space science	5.42	5.92	5.11
Engineering and technology .	4.73	4.39	4.42
Mathematics	5.67	5.10	4.73
	relative citation ratio(3)		
World citations to Canada:			
Clinical medicine	1.07	1.03	1.01
Biomedical research	0.84	0.82	0.85
Biology	1.14	0.99	1.01
Chemistry	1.54	1.49	1.35
Physics	0.99	0.94	0.97
Earth and space science	1.02	0.82	0.73
Engineering and technology .	1.25	1.16	0.99
Mathematics	0.75	0.87	0.93
International citations to Canada:			
Clinical medicine	0.90	0.82	0.75
Biomedical research	0.67	0.61	0.57
Biology	0.80	0.60	0.53
Chemistry	1.19	1.08	0.88
Physics	0.77	0.69	0.63
Earth and space science	0.77	0.57	0.50
Engineering and technology .	0.94	0.82	0.65
Mathematics	0.56	0.61	0.63

(1) Refers to the publication year of the cited paper.

(2) World citations include citations made to Canadian-authored papers by other Canadian-authored papers. International citations include citations made to Canadian-authored papers by non-Canadian-authored papers.

(3) A citation ratio of 1.00 reflects no over- or under-citing of Canadian S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of Canadian papers produced for that year.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Table 5 presents the international use made of each of the selected countries' publication output: RCR values again appear to be low. This is due in part to the definition used for 'international citations'. As was the case for publication output levels, the U.S.A. is the predominant source of the world's citations. The calculation of the denominator component of the RCR's numerator, i.e. 'the number of citations made by the world to world-authored papers less the number of citations made by the country under review to world-authored papers', is strongly influenced by the U.S.A.'s tendency to cite its fellow national researchers.(9)

Putting aside the value interpretation of the RCR, it appears that for the U.S.A., the U.K. and Canada, more recently published papers generally have less of an impact than earlier papers. The upward movement of the RCR values in biology and earth and space science for West Germany is noted. French-authored papers indicate an increasing relative influence from 1973 to 1981 in biomedical research and, to some extent, in the engineering and technology area.

Table 5. Relative Citation Ratios for Selected Countries, by Field

Field and country	1973(1)	1977	1981
	relative citation ratio(2)		
Biology			
International citations to(3):			
United States	0.71	0.69	0.61
United Kingdom	1.01	0.88	0.62
West Germany	0.53	0.71	0.73
France	0.79	0.39	0.42
Japan	0.42	0.37	0.38
Canada	0.80	0.60	0.53
Biomedical research			
International citations to:			
United States	1.10	1.06	0.92
United Kingdom	0.94	0.83	0.72
West Germany	0.63	0.66	0.69
France	0.37	0.40	0.52
Japan	0.52	0.49	0.51
Canada	0.67	0.61	0.57
Chemistry			
International citations to:			
United States	1.21	1.14	0.98
United Kingdom	1.03	0.85	0.82
West Germany	0.72	0.79	0.68
France	0.51	0.49	0.55
Japan	0.49	0.49	0.46
Canada	1.19	1.08	0.88

Table 5 continued

Physics			
International citations to:			
United States	1.21	1.16	1.00
United Kingdom	0.91	0.82	0.72
West Germany	0.86	0.90	0.89
France	0.73	0.73	0.68
Japan	0.50	0.46	0.40
Canada	0.77	0.69	0.63
Clinical medicine			
International citations to:			
United States	1.03	0.99	0.89
United Kingdom	0.91	0.83	0.72
West Germany	0.32	0.39	0.38
France	0.31	0.32	0.36
Japan	0.42	0.44	0.39
Canada	0.90	0.82	0.75
Earth and space science			
International citations to:			
United States	1.06	1.04	0.97
United Kingdom	0.94	0.84	0.73
West Germany	0.64	0.71	0.72
France	0.53	0.58	0.58
Japan	0.43	0.51	0.48
Canada	0.77	0.57	0.50
Engineering and technology			
International citations to:			
United States	0.92	0.80	0.67
United Kingdom	0.82	0.67	0.49
West Germany	0.38	0.41	0.38
France	0.44	0.67	0.54
Japan	0.48	0.52	0.53
Canada	0.94	0.82	0.65

Table 5 concluded

Mathematics			
International citations to:			
United States	0.91	0.85	0.70
United Kingdom	0.90	0.90	0.76
West Germany	0.41	0.51	0.36
France	0.47	0.36	0.54
Japan	0.43	0.49	0.33
Canada	0.56	0.61	0.63

(1) Refers to the publication year of the cited paper.

(2) A citation ratio of 1.00 reflects no over- or under-citing of Canadian S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of papers produced by that country for that year.

(3) International citations include citations made to Canadian-authored papers by non-Canadian-authored papers, and so on for other countries.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

In Table 6, citations by U.S. authors to papers authored by residents of the U.K. and Canada are compared. In total, Canadian research would seem to be at least as relevant to U.S. authors as is British research. Again, Canadian research, in at least some chemistry specialties is quite influential to U.S. researchers.

Table 6. U.S. Use of Canadian- and British-Authored Papers, by Field

Field	1973		1977		1981	
	Canadian	British	Canadian	British	Canadian	British
	relative citation ratio(1)					
Clinical medicine	0.91	0.78	0.85	0.68	0.78	0.58
Chemistry	1.35	1.05	1.19	0.87	1.02	0.89
Biomedical research	0.68	0.87	0.60	0.76	0.57	0.65
Physics	0.76	0.88	0.68	0.77	0.60	0.67
Engineering and technology ...	0.93	0.73	0.84	0.59	0.68	0.46
Biology	0.84	0.81	0.66	0.69	0.60	0.49
Earth and space science	0.72	0.80	0.54	0.73	0.50	0.64
Mathematics	0.57	0.88	0.65	0.81	0.69	0.81

1) A citation ratio of 1.00 reflects no over- or under-citing of a country's S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of papers produced by that country for that year.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Citations by researchers in the U.K. to work by Canadian and U.S. residents are presented in Table 7. The influence of some of the chemical research papers from Canada is again apparent. As well, research papers attributed to Canadians in biology and clinical medicine, while not having citation ratios of greater than one, compare favourably to the work of U.S. researchers.

Table 7. British Use of Canadian- and U.S.-Authored Papers, by Field

Field	1973		1977		1981	
	Canadian	U.S.	Canadian	U.S.	Canadian	U.S.
	relative citation ratio(1)					
Clinical medicine	0.93	0.91	0.85	0.89	0.73	0.79
Chemistry	1.45	1.33	1.24	1.33	1.18	1.09
Biomedical research	0.66	1.05	0.64	0.99	0.60	0.89
Physics	0.83	1.27	0.82	1.21	0.74	1.02
Engineering and technology	0.86	0.82	0.74	0.72	0.69	0.66
Biology	0.77	0.60	0.55	0.59	0.45	0.55
Earth and space science	0.87	1.03	0.60	1.04	0.55	0.98
Mathematics	0.68	0.78	0.78	0.87	0.59	0.75

(1) A citation ratio of 1.00 reflects no over- or under-citing of a country's S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of papers produced by that country for that year.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Finally, in Table 8, citations by Canadian authors to the work of British and U.S. researchers are compared. Overall, papers from both communities have a fairly strong impact on Canadian research with the U.S. papers appearing to be generally more frequently cited.

Table 8. Canadian Use of British- and U.S.-Authored Papers, by Field

Field	1973		1977		1981	
	British	U.S.	British	U.S.	British	U.S.
	relative citation ratio(1)					
Clinical medicine	1.13	1.24	1.01	1.18	0.92	1.12
Chemistry	1.25	1.47	0.99	1.43	1.11	1.34
Biomedical research	1.13	1.22	0.93	1.20	0.77	1.06
Physics	1.12	1.31	0.97	1.24	0.91	1.09
Engineering and technology	0.92	1.02	0.80	0.91	0.35	0.84
Biology	1.06	0.82	0.88	0.81	0.67	0.76
Earth and space science	1.12	0.99	0.97	0.98	0.80	1.02
Mathematics	1.10	1.06	1.11	1.01	0.93	0.82

(1) A citation ratio of 1.00 reflects no over- or under-citing of a country's S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of papers produced by that country for that year.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

A final note:

As an alternative and complement to the above citation series, CHI also provides citation counts based on the publication year of the 'citing paper' rather than the 'cited paper'. With this indicator series, citation counts refer to the number of references made to previously published works (i.e., back to 1973) in papers published in the year under review. RCR's for the world use of Canadian-authored papers, based on the publication year of the citing paper, are presented in Appendix Table 6. Discussion is again limited since the data are available at the field level only. It appears as time passes there is a modest increase in the relative impact of Canada's research ouput for each of the eight fields.

The main reason for inclusion of this (alternative) indicator concerns bibliometric investigations currently underway (see References 3 and 7). These investigations (and in particular the work by H.F. Moed et al.) have examined the issue of measuring research impact by examining the citations a paper receives a few years (e.g., 0-3) after its publication. The indicator series provides a measure of short-term impact and is considered primarily as an indicator of the visibility of a research group in a particular research specialty. This new procedure identifies about a quarter of all citations in the SCI database. On the other hand, long-term impact, which considers a much longer period of a published paper's lifetime (in this case, from 1973 to the specified citing year) is considered primarily as an indicator of the permanent contribution made to a research specialty. Currently, no short-term citation data are available for this series.

In a recent study by Martin and Irvine (referenced earlier) it was suggested that the impact of a country's research output could be examined by dividing the number of citations a country receives by the number of papers it published. Using this method, Appendix Table 7 provides a comparison of short- and long-term indicators for two fields. For Canada, it seems there are no significant differences in time trends in the papers being cited (i.e., recent Canadian papers were as likely to be cited as older ones). To conclude, the differing values for long-term indicators presented in Appendix Tables 6 and 7 are noted. Using the Martin and Irvine methodology, the impact indicator is simply the number of citations a country receives divided by the number of papers published, for the specified period of time. In the CHI computation (i.e., the relative citation ratio), the impact indicator is calculated by dividing a country's percentage share of the world's citations by its percentage share of published papers, for a specified period of time; next, an adjustment is made for the size of a country's literature in the database by multiplying the above ratio by the proportion of the publications in the database for that country (see reference 9, page 27).

BIBLIOMETRICS AND THE SCIENCE LITERATURE INDICATORS DATA BANK

Bibliometric studies are based on the premise that scientific and technological (S&T) progress depend on research; the publication of research findings increases the S&T knowledge pool which in turn facilitates the development of new knowledge. In the science indicators report series of the U.S. National Science Board we read:

> "Scientific literature is one of the major direct outputs of research. Scientific and technical findings are generally published in professional journals and thus add to the body of world scientific knowledge since scientists and engineers of all countries generally have access to this body of knowledge. The findings may stimulate further research or be used in a variety of practical applications in other fields, many of which are unanticipated at the time of the original research...
>
> "One of the ways that scientists and engineers acknowledge the contribution of former research and seek to differentiate or support their own findings is through citing previous publications. Under the assumption that the most significant literature will be more frequently cited than routine literature, citation indicators are used to measure the influence and quality of research."(10)

Generally, counts of research papers are used to provide measures of research productivity; analyses of citations to these research papers provide measures of research impact. Methods currently under investigation include: the development of general research performance measurements for bibliometric (publications and citations) analyses, co-citation cluster analysis (bibliometric mapping of science), the converging partial indicators (bibliometric and peer-interviews) method for large research institutes and bibliometric micro-scale past performance measurements.(11)

From these investigations we see two separate policy uses for bibliometrics emerging: one for monitoring research and the other for evaluating it. As described by Anderson in **New Approaches to Research Policy Using Bibliometrics**, the monitoring of research aims at providing the policy (decision) maker with an accurate description of the state of a research system from which a qualitative judgement can be made. In addition to the descriptive information, the evaluation of research aims at providing a means to judge the quality or value of research. Much of the controversy concerning the use of bibliometric statistics surrounds this latter purpose. Still, their use is becoming more common:

> "Policy interest in bibliometrics has arisen with the increasing concern over scientific output. Freeman (1986) argues that the current phase of science and technology policy has as its major preoccupation the effective use of technology as a stimulus to economic recovery. Decision makers, according to Freeman, are 'constantly searching for some better means of evaluating the past and probable future performance of individuals, projects and institutions' and because of this, have become particularly interested in bibliometrics. Gibbons (1984) argues in a similar manner that evaluation is increasingly becoming an issue because 'government innovation policies are failing' and because 'there is a pressing need for impact assessments'. For whatever specific reasons, it is clear that there is an increasing tendency among policy makers and decision makers to consider bibliometrics."(12)

For a discussion of this and other issues addressing the appropriate use of bibliometric statistics as indicators of research productivity and impact, readers are referred to the above work by Anderson as well as works by F. Narin, H. Small, B. Martin and J. Irvine, and H. F. Moed.

The Science Literature Indicator series is derived from the analysis of all papers (i.e., articles, notes and reviews) published annually in over 2,000 journals which were monitored for the SCI in 1973.(11) The 1973 journal set has been held constant so that time series analysis can be made. For 1984, this journal set contained about 286,100 papers. Beginning with 1981, CHI has compiled an additional and alternative indicator series based on the 3,000 plus journals monitored for the SCI in 1981. For 1984, this revised journal set contained about 370,000 papers. Appendix Table 5 presents (for the seven country set) national shares of the world's research papers by field for 1981 and 1984, for both journal sets. Because of the international expansion of science, one might expect to see a redistribution of country shares. Figures based on the 1981 journal set are relatively consistent with the 1973 journal set values. For all fields combined, there is a small decrease in relative shares for three of the six countries while the other three country positions remain more-or-less the same: the corresponding increase is seen in the figures for the U.S.S.R. and 'Rest of world'. At the field level, noticable differences include: the publication output for France and the U.S.S.R. in mathematics; the output for Japan in engineering and technology; and of particular importance, the output for Canada in the field of biology (note also the output of West Germany). The U.S.A.'s relative shares show somewhat smaller representations in seven of the eight fields, the exception being mathematics. Details of Canadian research output for each of the 100 subfields are found in Appendix Table 2 for both the 1973 and 1981 journal sets. For clinical medicine, we note the difference in our world share for the subfields of veterinary medicine and addictive diseases: the updated journal set gives a less active impression for the more recent years. Comparing output levels by biology subfields for 1984, it appears again the 1981 journal set gives a slightly worse impression of our world participation rate for half of the ten specialties identified for this field.

In order that possible trends in international research activities may be examined, the statistics presented in this paper are based on the 1973 journal set. The following caveats are noted.

- The data are appreciably biased in favour of English-language journals; i.e., the scientific contributions of West Germany, France and Japan are underestimated.

  In **An Indicator of Excellence in Canadian Science**, MacAulay comments that in the 1973 SCI, less than 4% of all Canadian-authored papers were published in French, and of those, only 39% were cited, a significantly lower rate than for English-language papers (64%). He concludes that Canadian scientists as a whole publish heavily in the English-language mainstream of SCI journals, and their work tends to be more heavily cited when they do this.(12)

- The CHI methodology assigns articles to fields and subfields according to the journals in which they are published; i.e., problems can arise in relation to smaller specialties since many papers will fall into 'broadly defined' subfields because the journals in which they appeared cover many subfields.

  Field and subfield coverage are based on the manual classification (i.e., subjective/expert opinion) of each journal covered by the SCI. Papers are then classified on the basis of the journal in which they are published. Clearly, this procedure obscures differences between papers in different subject areas but within single journals. In many fields, there are large and important journals which are multidisciplinary with respect to the specialties within that field. Thus, subfields such as 'general physics' were created. As an example, a large portion of the papers in nuclear physics do not appear in the journals which can be assigned to the subfield of nuclear physics but instead appear in journals with a broader

physics orientation, such as **Physical Review**, which have been classified as general physics. Also, multidisciplinary journals, such as **Science**, which have papers from more than one major field, are fractionally assigned to the fields they cover. Approximately 100 journals are assigned in this way. More recent developments in bibliometrics involve the definition of scientific fields at the paper level. The reader is directed to References 3 and 12 and the work of the Centre for Research Planning (CRP), Philadelphia, for discussions on paper analyses.

- The trend data are based on a constant set of journals defined by the SCI journal set for 1973; i.e., newly emerging or fast growing areas of science may be under-represented since papers published in entirely new journals are not covered.

  To eliminate the effects of annual changes in journal coverage, CHI developed the concept of the 'fixed journal set'. At a given point in time, (in this case 1973) a journal set covered by the SCI is chosen such that the most important international journals in all fields which are covered at that time are included. The fixed journal set is maintained so that true trends can be isolated from spurious trends resulting from coverage changes. Concurrently each year's data from the full journal set of the SCI can be examined to take advantage of the coverage improvements made each year. Each succeeding yearly snapshot would improve the picture of the relative activities of each country in each field. The full journal set would provide the most up-to-date snapshot of the relative activities of countries; the fixed journal set provides information on trends.

- The SCI records all papers cited in the journals that it scans. A proportion of these cited papers is cited in journals not monitored by the SCI; i.e., such papers are omitted from the publication counts and therefore from the denominator of the 'Relative Citation Ratio' resulting in a possible over estimate for the series. This has little appreciable effect on the analysis since we are examining relative trends.

- While the SCI journals are considered to monitor the mainstream of output from the international S&T publication process, much work relevant to Canadian problems may be published in journals not in the 'mainstream'. This research, since it is not included in the SCI, will not be covered in this analysis. All countries would have a similar problem; i.e., the present methodology is biased towards 'international' or U.S. science.

Definitions

Under contract with the National Science Foundation, CHI has over the past 16 years performed a series of projects to develop indicators of international scientific activity. The selected set of indicators are listed in Table 8. Those presented in this report (Indicator series 1, 6, 5 and 2) are defined below. The indicators are available for eight major fields of science: Clinical Medicine, Chemistry, Biomedical Research, Physics, Engineering and Technology, Biology, Earth and Space Science and Mathematics. Indicator series 1 (National Publication Counts) is also available for 100 subfields. It is noted that in previous years, four additional indicators, 7 (country distribution among fields), 8 (country influence), 9 (country isolation/intergration), and 10 (field internationality/interactivity) were available from the data bank: they are no longer being generated.

Table 9. Science Literature Indicators 1984 Database: Summary of Indicators

Indicator Series	Short Title	Journal Set(1)	Country Set(2)	Years Covered (Annually)	Field Coverage (8 Fields)
1A	National Pub. Counts	1973	197 Countries	1973-1984	X(3)
1B	National Pub. Counts	1973 AUG	7 Countries	1973-1984	X(3)
1C	National Pub. Counts	1981	197 Countries	1981-1984	X(3)
1D	National Pub. Counts	1981 AUG	7 Countries	1981-1984	X(3)
2A	National Citation Indicators-by Year of Citing Paper	1973	7 Countries	1973-1984	X
2C	National Citation Indicators-by Year of Citing Paper	1981	7 Countries	1981-1984	X
2D	National Citation Indicators-by Year of Citing Paper	1981 AUG	7 Countries	1981-1984	X
3A	U.S. Sector Publication Counts by Field and Level(4)	1973	U.S. Only-7 Sectors	1973-1984	X
3B	U.S. Sector Publication Counts by Field and Level(4)	1981	U.S. Only-7 Sectors	1981-1984	X
4A	Active Institutions within U.S. Sectors	1973	U.S. Only-7 Sectors	1973-1980	
4C	Active Institutions within U.S. Sectors	1973	U.S. Only-7 Sectors	1981-1984	
5A	National Citation Indicators-by Year of Cited Paper	1973	7 Countries	1973-1984	X
5C	National Citation Indicators-by Year of Cited Paper	1981	7 Countries	1981-1984	X
5D	National Citation Indicators-by Year of Cited Paper	1981 AUG	7 Countries	1981-1984	X
6A	International Institutional Co-authorship	1973	21 Countries	1973-1984	X
6C	International Institutional Co-authorship	1981	21 Countries	1981-1984	X
11A	Journal Internationality	1973	21 Countries	1973-1984	X
11C	Journal Internationality	1981	21 Countries	1981-1984	X
12A	U.S Sector Co-authorship	1973	U.S. Only-7 Sectors	1973-1984	X
12C	U.S. Sector Co-authorship	1981	U.S. Only-7 Sectors	1981-1984	X

Table 9 concluded

13A	U.S. Sector Cross-Citations-by Year of Cited Paper	1973	U.S. Only-7 Sectors	1973-1984	X
13C	U.S. Sector Cross-Citations-by Year of Cited Paper	1981	U.S. Only-7 Sectors	1981-1984	X
13D	U.S. Sector Cross-Citations-by Year of Cited Paper	1981 AUG	U.S. Only-7 Sectors	1981-1984	X
14A	U.S. Sector Cross-Citations-by Year of Citing Paper	1973	U.S. Only-7 Sectors	1973-1984	X
14B	U.S. Sector Cross-Citations-by Year of Citing Paper	1981	U.S. Only-7 Sectors	1981-1984	X
14C	U.S. Sector Cross-Citations-by Year of Citing Paper	1981 AUG	U.S. Only-7 Sectors	1981-1984	X

(1) 1973 Journal Set: approximately 2,300 journals covered by the Science Citation Index (SCI) in 1973. All papers (articles, notes, reviews) for which the author gave an address are counted. For 1981, this journal set contained about 289,000 papers.

1973 Augmented (AUG) Journal Set: adds approximately 3% to 1973 journal set counts by adding counts for those papers without an author address, by assuming the country of the author is the country of the journal. The number of papers without an author address varies widely with country and field.

1981 Journal Set: approximately 3,100 journals covered by the SCI in 1981. All papers (articles, notes, reviews) for which the author gave an address are counted. For 1981 this journal set contained about 372,000 papers.

1981 AUG Journal Set: adds approximately 3% to 1981 journal set counts by adding counts for those papers without an author address, by assuming the country of the author is the country of the journal.

(2) 7 Country Set: the seven countries are the U.S.A., the U.K., West Germany, France, the U.S.S.R., Japan, Canada and Rest of world.
197 Country Set: Essentially all individual countries which are identifiable in the SCI tapes.
21 Country Set: includes 15 countries and 6 geopolitical regions.

(3) Includes counts for each of the 100 subfields.

(4) Level refers to basic or applied research.

Source: "Data User's Guide: Science Literature Indicators Data Bank, 1984", Computer Horizons, Inc., Haddon Heights, New Jersey, March 1987, Figure 1, page 2.

Indicators Series 1: National Publication Counts

National publication counts are the total number of research papers (articles, notes, and reviews) authored by scientists who list their affiliation at institutions within a given country. These counts have been tabulated on an annual basis for the years 1973 to 1984. The tabulations have been performed for each of the eight fields and 100 subfields. Counts are

fractionally assigned to field and country. If a paper has authors from institutions in two countries, the paper is divided evenly, crediting one half the paper to each country. Similarly, if a journal is assigned one-third to one subfield and two-thirds to another, then a paper in that journal goes one-third to the first subfield and two-thirds to the second subfield.

Indicator Series 6: International Institutional Co-authorships

Series 6 provides indicators of the number of papers co-authored by scientists at institutions in pairs of countries. Also available are three related indicators: 1) the number of co-authorships expressed as a percentage of publications participated in by a country; 2) the number of co-authorships expressed as a percentage of multi-authored publications participated in by a country; and 3) co-operation indices between sets of two countries.

Indicator Series 5: National Citation Indicators - by Publication Year of Cited Paper

National citation counts are the number of citations in papers authored by scientists in one country over a given period of time to papers authored by scientists from another country in a given year. Citations are summed for each individual publication year of the cited paper (1973-1984) over all subsequent citing years (1973 to 1984). For example, a 1976 citation count is the sum of citations from papers published during 1976 to 1984, to papers published in 1976. Again, the counts have been tabulated for cross-country citations among the seven country set and for the eight major fields. Two other countries have been identified; 'the world total' and 'the world-excluding-self', where self refers to a specific country from the seven country set.

A Relative Citation Ratio is another indicator available in this series. It is given for pairs of countries where one country refers to the 'citing country' and the other, the 'cited country'. It is calculated by computing the citing country's share of citations which reference papers from authors from the cited country for a particular year of publication (over all citing years), and then dividing that by the percent of the field's papers authored by the cited country (for the given cited year). Deviations from a value of 1.0 indicate high or low citation rates.

A high citation ratio implies that a country's papers are cited relatively frequently. A natural conclusion is that high citation implies high usage which implies high impact or importance, all else being constant. However, all else is not constant: there are country coverage biases, language barriers, differences in publication practices, and other influences. But there are undoubtedly genuine differences in impact between the papers published by different authors and from different institutions and countries.

Indicator Series 2: National Citation Indicators - by Publication Year of Citing Paper

As an alternative and complement to the above indicator, indicator series 2 provides national citation counts (by country pairs and fields) that are summed for the publication year of the citing paper, rather than the cited paper. For this indicator series, national citation counts are defined as the number of citations in papers authored by scientists in one country in a given year to papers authored by scientists from another country in all previous years. For example, a 1976 citation count is the sum of all citations from 1976 papers to published papers from all previous years (1973 to 1976). The counts have been tabulated for cross-country citations among the seven country set and for the eight major fields. As well data are available for the two aggregated countries 'world' and 'world-excluding-self'.

A Relative Citation Ratio is also available for this indicator series. It is a measure of the extent to which a country is citing anothers literature, after adjustments are made for the sizes of the two countries' literatures in the database. Similar to indicator series 5, the

ratio is given for pairs of countries where one country refers to the 'citing country' and the other, the 'cited country'. It is generated by computing the citing country's share of citations for a given cited year which reference papers from the cited country and then dividing that by the percent share of the field's papers authored by the cited country for the cited year; and then, this ratio is multiplied by the proportion of all citations from the citing country for the cited year as compared to all cited years combined.

The following definitions have been extracted from the report "Evaluative Bibliometrics: The use of publication and citation analyses in the evaluation of scientific activity", CHI, March 1976.

Journal: - a recurring collection of articles, (usually containing references) notes and reviews and other material written by different authors reporting on research activity for purposes of professional communication.

Citation: - acknowledgement that one bibliometric unit receives from another.

Citation index: - a structured list of all the citations to a given collection of publications usually arranged so that each cited publication is followed by those publications which refer to it.

Citation analysis: - the evaluation and interpretation of the citations received by scientists, universities, countries and other aggregates of scientific activity, used as a measure of scientific influence and productivity, as well as a tool for measuring communication links.

Bibliometrics: - the quantitative measurement of the properties of a literature, usually as an aid in exploring the production, distribution and utilization of its contents.

Field: - a subject discipline or an area of research.

Subfield: - a component area of a field.

Concluding remarks:

A publication count is a simple definition of research output; while not perfect, it provides a reasonable approach to measuring research productivity within scientific disciplines. Citation analysis adds both a quality dimension to the publication count and a linkage measure. This paper has highlighted some of the major theoretical and practical concerns associated with their use as indicators of research output. To conclude, a few key areas for concern in the development of an appropriate program for producing these statistics are presented.

The first concern is the definition of research areas. The most common procedure for defining research disciplines has been based on the classification of journals. The papers are then assigned to those areas to which their journals of publication have been classified. As is evident from the information presented here, this procedure has its limitations. The optimum method for defining research areas would involve the classification of the papers themselves. In an effort to present more specific disciplines, recent bibliometric techniques have employed this method. The major drawback of this method is the requirement for extensive manual and computational time.

Because of the appearance and disappearance of journals, it is also important to maintain two sets of journals to monitor research activities. The first, the 'fixed journal set', remains constant for every year of analysis in order to obtain data on research trends; the second is updated annually in order to examine current relative activities of the units of analysis and to identify newly active areas.

Secondly, it is important to ensure that there is complete coverage of publication and citation data. While it has been said many times that the SCI offers the most comprehensive set of data on the international scientific community, a Canadian program should have a special concern for the internal functioning of its scientific community. Under ISI's current literature coverage, there is a tendency to neglect papers from authors (journals, research areas and countries) which are peripheral to the mainstream of publication activity. ISI coverage could be augmented with those journals identified as being important to Canadian research. As well, as bibliometric studies focus on the examination of 'smaller' units of analysis, (i.e., a research group, department, or specialty) combinations of data from several international literature bases and from expert opinion become increasingly important to the analysis.

In the calculation of statistics, attention must be paid to the rules for including/excluding data records. For example, all authors of a paper should be included and not just first authors, and all papers should be considered. As seen by the national publication counts at the subfield level, bibliometric statistics for Canada can often be based on relatively low numbers. Omissions (and small errors) can lead to dramatic differences in results and interpretations. Again, in the more recent cases of impact analysis, it has been suggested that, at the research group level, bibliometric analyses employ data from more than one data source.

Finally, in citation analysis, it is important to assess the adequacy of the number of cited years. Citations to a paper accumulate at varying rates depending on the research specialty. A time lapse of less than three years may be sufficient for certain areas yet inadequate for others.

To conclude, there are several approaches to bibliometric (publication and citation) analyses, providing different levels of detail for different units of study. The most suitable approach depends on the type of information required. Readers are reminded that the statistics in this paper have been presented as examples of the type of information available from a bibliometric analysis of scientific journals and research papers. Comments and suggestions are invited for the development of an appropriate series of bibliometric indicators for Canada.

REFERENCES

(1) The term bibliometrics was coined in 1969 by Alan Pritchard, who defined it as "the application of mathematics and statistical methods to books and other media of communication". A large body of literature has been written on this subject and resultant analyses, and several mathematical expressions have been established to describe the workings of science. For example, 'Bradford's Law' describes how the literature on a particular subject is distributed among journals; the 'Pratt Index' measures the degree to which papers on a given subject are concentrated within a journal collection; and, 'Lotka's Law' describes the productivity distribution among scientists, e.g., how many scientists will author ten or more papers. While these laws (and others) each apply to a different specific phenomenon, they all tend to demonstrate one thing: that a few (journals, scientists, etc.) account for the many (papers, citations). Stephen J. Bensman, "Journal Collection Management as a Cumulative Advantage Process", **College and Research Libraries**, January 1985, pp. 13-29.

(2) The Science Citation Index is a calendar-year index to scientific literature monitored by the Institute for Scientific Information, Inc. It covers all items from all issues of the SCI journals (ie., journals published and available to ISI during the time period covered). The SCI, first published in 1964, finds its origins in the construction of a citation index to genetics literature which was initiated by Dr. E. Garfield, ISI, in the late 1950s.

(3) **Evaluation of National Research Performance in Basic Research. A Review of Techniques for Evaluating National Performance in Basic Research, with Case Studies in Genetics and Solid State Physics**, Advisory Board for the Research Councils, ABRC Science Policy Studies No. 1, London, 1986, pp. 113-119, 310.

(4) R. Hooghiemstra, "An Atlas of Science, Sidestepping discipline limitations a great advantage of cluster analysis", **Science Policy in the Netherlands**, Volume 7, No. 2, Ministry of Education and Science, May 1985, pp. 12-14.

(5) J. MacAulay, **An Indicator of Excellence in Canadian Science**, Statistics Canada, Catalogue No. 88-501E, 1985, p. 12.

(6) **Science Indicators 1982**, National Science Board, Washington, D.C., 1983, p. 29.

(7) H.F. Moed et al., **On the Measurement of Research Performance: the Use of Bibliometric Indicators**, Leiden, the Netherlands, 1986.

(8) CHI, Inc. has recently made available for purchase a tape containing the citation indicator data at the subfield level.

(9) As outlined in the text, to determine the international use of a country's research output CHI includes as part of its citation calculation (i.e., more specifically, the denominator of the numerator component of the RCR) all national citations by all countries other than the country under review. If all national citations were excluded for this definition, results would differ. For example, for the international use of Canadian-authored research define the RCR as:

for a given field and year,

$$RCR = \frac{\text{no. of citations by world to Canadian-authored paper} - \text{no. of citations by Canada to Canadian-authored papers}}{\text{no. of citations by world to international-authored papers} - \text{no. of citations by Canada to international-authored papers}}$$

$$\frac{\text{no. of Canadian-authored papers in the database}}{\text{no. of research papers in the database}}$$

The following results apply for

International Citations to **Canadian-Authored Papers, by Field**

Field	Year		
	1973	1977	1981
Canada's share of international citations:	percent		
Clinical medicine	5.77	6.03	6.01
Biomedical research	5.62	5.05	5.24
Biology	12.64	10.83	10.87
Chemistry	8.15	7.79	6.21
Physics	4.93	4.37	3.81
Earth and space science	8.39	6.96	5.88
Engineering and technology .	8.80	7.91	7.58
Mathematics	6.56	6.61	7.28
International citations to Canada:	relative citation ratio		
Clinical medicine	1.73	1.65	1.68
Biomedical research	1.23	1.17	1.21
Biology	1.57	1.26	1.29
Chemistry	2.12	2.11	1.93
Physics	1.32	1.26	1.27
Earth and space science	1.55	1.18	1.15
Engineering and technology .	1.86	1.80	1.71
Mathematics	1.16	1.30	1.54

(10) **Science Indicators 1982,** op.cit., pp. 11-12.

(11) A.F.J. Van Raan, "Indicators of National Strength and Weakness by Micro-scale Monitoring of Research Performance", OECD, DSTI 2957S, Paris, December 1986.

(12) F. Anderson, **New Approaches to Research Policy Using Bibliometrics**, Conseil de la science et de la technologie, February 1987, p. 11.

(13) F. Narin, "Measuring the Research Productivity of Higher Education Institutions using Bibliometric Techniques", OECD, DSTI/SPR/85.24/07 B, Paris, May 1985, p. 11: ...there are approximately 25,000 journals published in the world today. The SCI currently monitors only 3,100 of them, however these journals are considered to cover the central core of the world's scientific literature, containing at least 75% of all of the science which is of international relevance.

The selection of journals by the Institute for Scientific Information for inclusion in its information systems is based on the international use of the publications and includes a large-scale citation analysis of the most frequently cited journals.

(14) J. MacAulay, **An Indicator of Excellence in Canadian Science,** op.cit., p. 17.

APPENDIX TABLES

Appendix

Table 1. National Shares of the World's Research Papers, by Field(1)

Field and country	1973-1976		1977-1980		1981-1984	
	average number	percent	average number	percent	average number	percent
All fields						
United States.....	100,273	37.7	98,708	36.9	106,130	36.8
United Kingdom.....	24,703	9.3	22,834	8.5	23,804	8.3
West Germany.....	16,801	6.3	17,087	6.4	17,651	6.1
France.....	14,893	5.6	14,341	5.4	14,564	5.0
U.S.S.R.	22,001	8.3	21,371	8.0	22,132	7.7
Japan.....	14,425	5.4	17,049	6.4	21,211	7.4
Canada.....	11,603	4.4	11,423	4.3	11,993	4.2
Rest of world.....	61,528	23.1	65,026	24.3	70,982	24.6
World.....	266,227	100.0	267,837	100.0	288,466	100.0
Clinical medicine						
United States.....	32,146	42.7	34,267	41.1	36,630	42.1
United Kingdom.....	7,781	10.3	7,515	9.4	8,390	9.6
West Germany.....	5,275	7.0	5,063	6.4	5,159	5.9
France.....	4,208	5.6	4,401	5.5	4,649	5.3
U.S.S.R.	2,067	2.7	2,098	2.6	2,217	2.5
Japan.....	2,934	3.9	3,732	4.7	5,050	5.8
Canada.....	2,566	3.4	2,887	3.6	3,134	3.6
Rest of world.....	18,226	24.2	19,579	24.6	21,819	25.1
World.....	75,201	100.0	82,843	100.0	87,048	100.0
Chemistry						
United States.....	9,725	22.3	9,138	21.2	9,816	21.3
United Kingdom.....	3,511	8.0	3,028	7.0	2,967	6.4
West Germany.....	2,849	6.5	3,030	7.0	3,095	6.7
France.....	2,993	6.8	2,494	5.8	2,495	5.4
U.S.S.R.	6,828	15.6	6,710	15.6	7,046	15.3
Japan.....	4,000	9.2	4,452	10.3	5,306	11.5
Canada.....	1,593	3.6	1,470	3.4	1,449	3.1
Rest of world.....	12,203	27.9	12,775	29.6	13,848	30.1
World.....	43,702	100.0	43,078	100.0	46,020	100.0
Biomedical research						
United States.....	15,974	38.7	17,010	39.5	18,744	40.6
United Kingdom.....	3,918	9.5	3,754	8.7	3,799	8.2
West Germany.....	2,486	6.0	2,591	6.0	2,781	6.0
France.....	2,836	6.9	2,582	6.0	2,385	5.2
U.S.S.R.	2,505	6.1	2,643	6.1	2,834	6.1
Japan.....	1,787	4.3	2,361	5.5	3,028	6.6
Canada.....	1,814	4.4	1,824	4.2	2,023	4.4
Rest of world.....	9,911	24.0	10,300	23.9	10,624	23.0
World.....	41,230	100.0	43,064	100.0	46,216	100.0

Table 1 continued

Physics						
United States.....	11,633	32.4	11,105	30.3	12,068	29.6
United Kingdom.....	2,640	7.4	2,318	6.3	2,463	6.0
West Germany.....	2,230	6.2	2,470	6.7	2,840	7.0
France.....	2,007	5.6	2,150	5.9	2,407	5.9
U.S.S.R.	6,073	16.9	5,972	16.3	6,340	15.6
Japan.....	2,406	6.7	2,922	8.0	3,577	8.8
Canada.....	1,284	3.6	1,267	3.5	1,228	3.0
Rest of world.....	7,623	21.2	8,427	23.0	9,792	24.0
World.....	35,894	100.0	36,629	100.0	40,714	100.0
Engineering and technology						
United States.....	10,995	41.3	9,314	39.9	9,790	41.6
United Kingdom.....	2,859	10.8	2,239	9.6	2,026	8.6
West Germany.....	2,032	7.7	1,819	7.8	1,750	7.4
France.....	752	2.8	770	3.3	751	3.2
U.S.S.R.	2,728	10.3	2,200	9.4	1,785	7.6
Japan.....	1,469	5.5	1,559	6.7	1,850	7.9
Canada.....	1,268	4.8	1,004	4.3	1,036	4.4
Rest of world.....	4,446	16.8	4,419	18.9	4,570	19.4
World.....	26,508	100.0	23,323	100.0	23,572	100.0
Biology						
United States.....	10,706	45.3	9,929	42.0	10,997	43.1
United Kingdom.....	2,377	10.0	2,451	10.4	2,608	10.2
West Germany.....	889	3.8	967	4.1	907	3.6
France.....	932	3.9	894	3.8	803	3.1
U.S.S.R.	367	1.6	349	1.5	371	1.5
Japan.....	1,250	5.3	1,443	6.1	1,714	6.7
Canada.....	1,926	8.1	1,963	8.3	2,129	8.3
Rest of world.....	5,209	22.0	5,631	23.8	5,981	23.4
World.....	23,657	100.0	23,626	100.0	25,511	100.0
Earth and space science						
United States.....	5,369	45.9	5,060	44.2	5,486	43.5
United Kingdom.....	1,002	8.6	1,039	9.1	1,091	8.6
West Germany.....	420	3.6	461	4.0	562	4.5
France.....	552	4.7	471	4.1	585	4.6
U.S.S.R.	1,209	10.3	1,110	9.7	1,256	10.0
Japan.....	251	2.1	260	2.3	286	2.3
Canada.....	649	5.5	668	5.8	694	5.5
Rest of world.....	2,255	19.3	2,370	20.7	2,657	21.1
World.....	11,706	100.0	11,438	100.0	12,615	100.0

Table 1 concluded

Mathematics						
United States.....	3,767	45.2	2,887	40.4	2,599	38.3
United Kingdom.....	615	7.4	490	6.9	462	6.8
West Germany.....	621	7.5	688	9.6	558	8.2
France.....	614	7.4	580	8.1	488	7.2
U.S.S.R.	225	2.7	290	4.1	284	4.2
Japan.....	330	4.0	320	4.5	401	5.9
Canada.....	504	6.1	341	4.8	302	4.5
Rest of world.....	1,654	19.9	1,545	21.6	1,692	24.9
World.....	8,330	100.0	7,139	100.0	6,785	100.0

(1) When a paper is authored by researchers from more than one country, that paper is prorated across the countries involved. For example, if a given paper has several authors from France and Canada, it is divided evenly, crediting one half the paper to each country.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 2. Canada's Share of the World's Research Papers, by Subfield, 1984

Field and subfield	1973 Journal Set Number of research papers			1981 Journal Set(1) Number of research papers		
	World	Canada	% of world	World	Canada	% of world
All fields	286,120	12,298	4.3	369,905	15,611	4.2
Clinical medicine	87,601	3,274	3.7	119,079	4,478	3.8
General and internal medicine	14,559	405	2.8	17,553	435	2.5
Allergy	628	29	4.6	702	33	4.7
Anesthesiology	1,167	86	7.4	1,325	94	7.1
Cancer	4,013	118	2.9	5,919	173	2.9
Cardiovascular system	3,619	100	2.8	4,993	143	2.9
Dentistry	1,906	63	3.3	2,435	67	2.8
Dermatology & venereal diseases.	1,322	7	0.5	2,853	44	1.5
Endocrinology	3,418	148	4.3	4,494	193	4.3
Fertility	965	59	6.1	1,178	71	6.0
Gastroenterology	1,693	34	2.0	1,909	40	2.1
Geriatrics	435	23	5.3	765	31	4.1
Hematology	1,577	53	3.4	2,227	80	3.6
Immunology	6,431	232	3.6	7,918	276	3.5
Obstetrics and gynecology	1,704	101	5.9	2,319	125	5.4
Neurology and neurosurgery	6,642	322	4.8	10,472	590	5.6
Ophthalmology	1,757	82	4.7	2,363	96	4.1
Orthopedics	766	25	3.3	1,150	43	3.7
Arthritis and rheumatism	498	16	3.2	903	73	8.1
Otorhinolaryngology	890	20	2.2	1,392	34	2.4
Pathology	2,493	89	3.6	2,928	104	3.6
Pediatrics	2,558	99	3.9	2,823	103	3.6
Pharmacology	8,175	282	3.1	10,901	435	4.0
Pharmacy	3,203	48	1.5	4,050	57	1.4
Psychiatry	1,962	66	3.4	2,289	72	3.1
Radiology and nuclear medicine	3,360	77	2.3	5,108	210	4.1
Respiratory system	1,412	101	7.2	1,556	105	6.7
Surgery	3,906	251	6.4	5,026	279	5.6
Tropical medicine	566	7	1.2	645	8	1.2
Urology	944	24	2.5	1,642	38	2.3
Nephrology	332	13	3.9	521	24	4.6
Veterinary medicine	2,782	200	7.2	5,476	235	4.3
Addictive diseases	246	18	7.3	443	29	6.5
Hygiene and public health	1,359	46	3.4	2,408	103	4.3
Miscellaneous clinical medicine.	313	30	9.6	393	35	8.9

Table 2 continued

Chemistry	45,440	1,413	3.1	54,117	1,605	3.0
Analytical chemistry	5,045	145	2.9	5,884	162	2.8
Organic chemistry	7,362	197	2.7	8,155	217	2.7
Inorganic & nuclear chemistry	2,645	64	2.4	4,224	88	2.1
Applied chemistry	2,306	35	1.5	2,365	35	1.5
General chemistry	14,823	558	3.8	16,438	588	3.6
Polymers	3,663	100	2.7	4,118	122	3.0
Physical chemistry	9,596	314	3.3	12,913	393	3.0
Biomedical research	45,165	2,059	4.6	56,217	2,454	4.4
Physiology	3,416	355	10.4	3,910	371	9.5
Anatomy and morphology	671	55	8.2	822	59	7.2
Embryology	782	32	4.1	1,001	38	3.8
Genetics and heredity	3,576	138	3.9	4,574	190	4.2
Nutrition and dietetics	1,318	52	3.9	1,664	63	3.8
Biochemistry and molecular biology	15,084	589	3.9	19,042	710	3.7
Biophysics	870	27	3.1	974	34	3.5
Cell biology, cytology and histology	3,886	165	4.2	5,114	189	3.7
Microbiology	3,360	211	6.3	4,640	272	5.9
Virology	1,605	72	4.5	1,861	81	4.4
Parasitology	867	48	5.5	1,236	55	4.4
Biomedical engineering	882	67	7.6	1,532	114	7.4
Microscopy	248	14	5.6	387	18	4.7
Miscellaneous biomedical research	1,007	54	5.4	1,521	75	4.9
General biomedical research	7,593	180	2.4	7,939	185	2.3
Physics	40,416	1,274	3.2	46,448	1,455	3.1
Chemical physics	4,440	230	5.2	5,327	282	5.3
Solid state physics	7,149	190	2.7	8,297	230	2.8
Fluids and plasmas	894	27	3.0	1,030	30	2.9
Applied physics	9,367	234	2.5	10,302	243	2.4
Acoustics	1,129	39	3.5	1,129	39	3.5
Optics	1,493	64	4.3	1,939	74	3.8
General physics	11,769	306	2.6	13,449	327	2.4
Nuclear and particle physics	3,365	130	3.9	3,814	164	4.3
Miscellaneous physics	810	54	6.7	1,161	66	5.7

Table 2 concluded

Engineering and technology	22,996	1,068	4.6	30,310	1,352	4.5
Chemical engineering	2,616	167	6.4	3,003	177	5.9
Mechanical engineering	1,934	62	3.2	3,035	93	3.1
Civil engineering	990	56	5.7	1,927	109	5.7
Electrical engineering and electronics	6,825	329	4.8	7,421	348	4.7
Miscellaneous engineering and technology	.	.	--	632	35	5.5
General engineering	991	18	1.8	1,046	19	1.8
Metals and metallurgy	3,292	174	5.3	3,854	178	4.6
Materials science	2,207	136	6.2	3,719	172	4.6
Nuclear technology	1,832	38	2.1	2,004	42	2.1
Aerospace technology	716	14	2.0	990	42	4.2
Computers	1,115	57	5.1	1,860	94	5.1
Library & information science	92	.	--	231	12	5.2
Operation research & management science	386	17	4.4	540	27	5.0
Industrial engineering	.	.	--	48	4	8.3
Biology	25,488	2,194	8.6	38,092	2,812	7.4
General biology	1,269	39	4.0	1,594	41	2.6
General zoology	1,137	275	24.2	2,122	279	13.2
Entomology	1,807	186	10.3	3,017	212	7.0
Miscellaneous zoology	2,376	151	6.4	3,027	169	5.6
Marine biology & hydrobiology	1,841	245	13.3	3,419	357	10.4
Botany	7,156	483	6.7	9,490	673	7.1
Ecology	1,486	82	4.7	2,770	239	8.6
Agriculture and food science	5,964	446	7.5	8,527	499	5.9
Dairy and animal science	2,035	282	13.9	3,315	309	9.3
Miscellaneous biology	417	5	1.2	811	34	4.2
Earth and space science	12,684	746	5.9	16,333	1,030	6.3
Astronomy and astrophysics	3,650	167	4.4	3,759	170	4.5
Meteorology and atmospheric science	1,174	39	3.3	1,545	57	3.7
Geology	1,795	130	7.2	2,907	209	7.2
Earth and planetary science	4,895	355	7.3	6,431	505	7.9
Geography	20	.	--	55	4	7.3
Oceanography and limnology	1,150	55	4.8	1,636	85	5.2
Mathematics	6,330	270	4.3	9,309	425	4.6
Probability and statistics	985	54	5.5	1,481	82	5.5
Applied mathematics	834	37	4.4	1,674	83	5.0
General mathematics	4,071	169	4.2	4,706	181	3.8
Miscellaneous mathematics	440	10	2.3	1,448	79	5.5

(1) Starting with 1981, CHI expanded its analysis to also include the analysis of all papers published annually in the journals which were monitored for the SCI in 1981.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 3. International Co-authorship Linkages with Canada, by Field

Field and country	1973-1976		1977-1980		1981-1984	
	average number	percent	average number	percent	average number	percent
Clinical medicine						
United States	172	61	225	59	327	59
United Kingdom	43	15	43	11	50	9
West Germany	5	2	4	1	11	2
France	15	5	32	9	46	8
Japan	4	1	6	2	13	2
Rest of world	43	15	69	18	108	19
Total co-authorships with foreign countries	280	21	379	23	555	27
Co-authorships within Canada	1,058	79	1,272	77	1,470	73
Chemistry						
United States	76	42	71	33	111	36
United Kingdom	30	17	40	19	52	17
West Germany	6	4	11	5	17	6
France	13	7	25	12	31	10
Japan	2	1	8	4	12	4
Rest of world	53	30	60	28	85	28
Total co-authorships with foreign countries	181	54	215	59	308	62
Co-authorships within Canada	156	46	148	41	187	38
Biomedical research						
United States	119	54	154	53	212	52
United Kingdom	32	15	36	13	40	10
West Germany	9	4	11	4	16	4
France	13	6	23	8	40	10
Japan	3	2	4	1	10	2
Rest of world	43	20	63	22	88	22
Total co-authorships with foreign countries	219	37	290	41	404	42
Co-authorships within Canada	380	63	419	59	566	58

Table 3 continued

Physics						
United States	112	46	144	43	157	37
United Kingdom	27	11	36	11	46	11
West Germany	10	4	16	5	25	6
France	22	9	33	10	40	10
Japan	7	3	16	5	20	5
Rest of world	66	27	94	28	135	32
Total co-authorships with foreign countries	244	64	290	65	404	68
Co-authorships within Canada	140	36	179	33	200	32
Engineering and technology						
United States	72	52	71	46	84	41
United Kingdom	18	13	21	13	23	11
West Germany	3	2	5	3	8	4
France	7	5	7	5	10	5
Japan	3	2	.6	4	12	6
Rest of world	35	26	45	29	69	34
Total co-authorships with foreign countries	137	45	153	50	204	55
Co-authorships within Canada	164	55	151	50	167	45
Biology						
United States	84	55	108	54	138	54
United Kingdom	18	12	22	11	19	8
West Germany	4	3	5	3	9	3
France	4	3	7	3	12	5
Japan	3	2	3	2	6	2
Rest of world	38	25	54	27	71	28
Total co-authorships with foreign countries	152	33	199	37	254	37
Co-authorships within Canada	301	67	344	63	432	63
Earth and space science						
United States	86	58	105	54	130	49
United Kingdom	18	12	23	12	35	13
West Germany	5	3	11	5	15	6
France	5	3	9	5	16	6
Japan	2	1	3	1	3	1
Rest of world	33	22	45	23	64	24
Total co-authorships with foreign countries	149	62	195	60	263	63
Co-authorships within Canada	93	38	131	40	152	37

Table 3 concluded

Mathematics						
United States	71	53	59	51	66	47
United Kingdom	15	11	12	10	14	10
West Germany	7	5	8	7	9	6
France	6	4	6	5	7	5
Japan	2	1	1	1	2	1
Rest of world	35	26	31	26	44	31
Total co-authorships with foreign countries	134	82	116	83	82	89
Co-authorships within Canada	29	18	23	17	18	11

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 4. World Use of U.S.-Authored Papers, by Field

Field	Year(1) 1973	1975	1977	1979	1981
	relative citation ratio(2)				
World citations to the U.S.A.(3):					
Clinical medicine	1.35	1.36	1.34	1.34	1.33
Biomedical research	1.42	1.41	1.43	1.38	1.36
Biology	1.08	1.11	1.16	1.15	1.15
Chemistry	1.64	1.68	1.69	1.72	1.67
Physics	1.54	1.53	1.56	1.56	1.49
Earth and space science	1.37	1.44	1.39	1.45	1.43
Engineering and technology	1.28	1.27	1.27	1.29	1.23
Mathematics	1.24	1.22	1.27	1.24	1.25
International citations to the U.S.A.:					
Clinical medicine	1.03	1.02	0.99	0.95	0.89
Biomedical research	1.10	1.07	1.06	0.99	0.92
Biology	0.71	0.69	0.69	0.66	0.61
Chemistry	1.21	1.18	1.14	1.09	0.98
Physics	1.21	1.17	1.16	1.12	1.00
Earth and space science	1.06	1.10	1.04	1.07	0.97
Engineering and technology	0.92	0.84	0.80	0.79	0.67
Mathematics	0.91	0.86	0.85	0.80	0.70

(1) Refers to the publication year of the cited paper.

(2) A citation ratio of 1.00 reflects no over- or under-citing of the American S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of U.S.-authored papers produced for that year.

(3) World citations include citations made to U.S.-authored papers by other U.S.-authored papers. International citations include citations made to U.S.-authored papers by non-U.S.-authored papers.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 5. Comparative Distribution of Country Shares of the World's Research Papers, by Field, for Two Journal Sets

Field and country	1973 Journal Set				1981 Journal Set		
	1981	1984	Average annual % change 1973-80	1981-84	1981	1984	Average annual % change
	percent						
All fields							
United States.....	36.9	36.6	-0.7	-0.7	35.9	35.4	-0.3
United Kingdom.....	8.4	8.1	-1.6	-1.6	8.3	8.2	-0.7
Japan.....	7.1	7.6	3.8	2.1	6.8	7.3	2.5
West Germany.....	6.3	6.0	0.5	-2.0	6.3	6.0	-1.8
France.....	5.2	5.0	-0.5	-1.8	5.0	4.8	-1.2
Canada.....	4.1	4.3	-0.9	1.3	3.9	4.2	2.6
U.S.S.R.	7.6	7.6	-1.9	-0.3	8.0	7.9	-0.2
Rest of world.....	24.5	24.9	1.4	0.1	25.7	26.1	0.6
No. of Papers.....	289,800	286,100	-0.1	-0.4	368,900	369,900	0.1
Clinical medicine							
United States.....	42.6	42.1	0.9	.	41.3	40.9	0.5
United Kingdom.....	9.6	9.7	-0.8	0.8	9.8	9.8	0.9
Japan.....	5.3	6.2	6.4	5.5	5.1	5.9	5.7
West Germany.....	6.1	5.6	-0.6	-2.6	6.4	5.9	-2.3
France.....	5.6	5.2	0.6	-2.1	5.2	4.8	-2.1
Canada.....	3.6	3.7	1.8	1.8	3.4	3.8	3.8
U.S.S.R.	2.6	2.4	-1.2	-2.8	3.3	3.1	-0.5
Rest of world.....	24.6	25.0	1.2	0.8	25.5	25.9	1.3
World.....	100	100	0.8	0.3	100	100	0.8
Chemistry							
United States.....	21.2	21.4	-1.7	-0.6	20.0	20.6	1.0
United Kingdom.....	6.5	6.0	-2.0	-3.2	6.6	6.1	-3.0
Japan.....	11.6	11.6	2.1	-1.1	10.9	10.6	-1.0
West Germany.....	7.0	6.5	2.1	-3.1	6.6	6.1	-2.8
France.....	5.8	5.2	-3.0	-4.4	5.9	5.3	-3.3
Canada.....	3.2	3.1	-2.3	-2.0	3.1	3.0	-1.2
U.S.S.R.	14.7	15.2	-1.2	0.7	16.7	17.3	1.2
Rest of world.....	30.1	31.0	2.1	0.1	30.3	31.1	0.7
World.....	100	100	-0.1	-1.0	100	100	-0.2

Table 5 continued

Biomedical research							
United States.....	40.4	40.4	1.3	-0.6	39.5	39.5	0.6
United Kingdom.....	8.2	7.8	-0.5	-2.1	8.5	8.3	-0.1
Japan.....	6.1	6.9	7.1	3.5	6.2	6.7	3.3
West Germany.....	6.0	5.8	1.9	-1.7	6.1	5.7	-1.8
France.....	5.4	5.1	-0.9	-2.2	5.2	5.0	-0.9
Canada.....	4.3	4.6	-0.8	1.3	4.1	4.4	3.0
U.S.S.R.	5.9	6.2	0.5	0.9	5.7	6.0	2.6
Rest of world.....	23.7	23.2	1.2	-1.4	24.7	24.5	0.3
World.....	100	100	1.1	-0.7	100	100	0.6
Physics							
United States.....	30.4	29.0	-0.3	-1.1	28.6	27.3	-0.9
United Kingdom.....	6.5	5.7	-2.9	-3.8	6.4	5.8	-2.4
Japan.....	8.8	8.7	4.9	-0.1	8.2	8.1	0.2
West Germany.....	6.7	7.2	3.8	2.9	6.7	7.3	3.2
France.....	5.7	6.2	3.6	2.9	5.9	6.5	4.0
Canada.....	3.0	3.2	0.2	2.2	2.9	3.1	3.0
U.S.S.R.	15.5	15.7	-1.3	0.9	16.8	16.5	0.1
Rest of world.....	23.4	24.4	3.0	2.0	24.4	25.4	2.1
World.....	100	100	0.8	0.5	100	100	0.7
Engineering and technology							
United States.....	41.3	40.8	-4.8	-1.8	40.7	39.5	-0.9
United Kingdom.....	8.9	8.1	-5.5	-4.5	8.5	7.7	-3.2
Japan.....	7.4	8.7	0.9	3.4	9.2	10.9	5.8
West Germany.....	7.6	7.6	-4.2	-2.2	7.0	7.0	-0.3
France.....	3.3	2.9	-0.6	-5.6	3.3	3.1	-2.5
Canada.....	4.4	4.6	-5.2	0.9	4.2	4.5	1.9
U.S.S.R.	7.9	7.3	-7.3	-4.6	7.6	7.0	-3.0
Rest of world.....	19.0	20.0	-0.4	0.1	19.5	20.4	1.5
World.....	100	100	-4.0	-1.6	100	100	-0.1
Biology							
United States.....	42.6	42.5	-2.0	-0.3	37.6	37.2	-1.3
United Kingdom.....	10.4	10.3	0.5	-0.6	9.0	9.1	-0.4
Japan.....	6.3	7.0	2.3	3.0	6.1	6.7	1.9
West Germany.....	3.6	3.8	0.7	1.6	4.7	4.7	-0.9
France.....	3.4	3.2	-2.1	-0.6	3.5	3.3	-2.7
Canada.....	7.7	8.6	-0.3	3.9	6.3	7.4	4.7
U.S.S.R.	1.4	1.6	-1.0	4.4	2.8	2.9	-0.7
Rest of world.....	24.5	23.0	1.0	-2.3	30.0	28.8	-2.3
World.....	100	100	-0.7	-0.3	100	100	-1.0

Table 5 concluded

Earth and space science							
United States.....	43.2	43.7	-1.9	1.1	42.7	41.3	-2.4
United Kingdom.....	8.9	8.3	1.9	-1.7	8.5	8.7	-0.3
Japan.....	2.2	2.6	2.2	6.9	2.3	2.5	1.8
West Germany.....	4.4	4.2	3.5	-0.9	4.4	4.1	-3.5
France.....	4.8	4.4	-0.6	-2.5	4.6	4.3	-2.9
Canada.....	5.1	5.9	-0.8	5.6	5.2	6.3	5.2
U.S.S.R.	10.2	9.8	-2.1	-0.4	10.0	9.5	-2.9
Rest of world.....	21.2	21.1	1.8	0.6	22.3	23.2	0.1
World.....	100	100	-0.7	0.7	100	100	-1.3
Mathematics							
United States.....	38.5	36.6	-6.1	-6.5	38.2	37.2	-4.2
United Kingdom.....	6.6	6.7	-3.9	-4.5	6.0	6.4	-1.7
Japan.....	5.3	6.2	-0.4	0.1	4.3	5.3	3.4
West Germany.....	10.7	7.3	1.4	-14.8	9.0	6.4	-12.6
France.....	6.6	8.1	-1.6	1.7	5.6	6.7	2.5
Canada.....	4.7	4.3	-6.3	-7.9	5.1	4.6	-6.7
U.S.S.R.	4.3	3.7	4.6	-9.8	7.6	5.9	-10.9
Rest of world.....	23.3	27.1	-1.1	-0.4	24.1	27.5	1.0
World.....	100	100	-3.6	-5.1	100	100	-3.4

Source: Science Literature Indicators Data Bank, Computer Horizons Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 6. International Use of Canadian-Authored Papers, by Field

Field	Publication year of citing paper				
	1975	1977	1979	1981	1984
	relative citation ratio(1)				
International citations to Canada(2):					
Clinical medicine	0.74	0.83	0.85	0.86	0.86
Biomedical research	0.59	0.64	0.64	0.66	0.67
Biology	0.55	0.63	0.64	0.68	0.66
Chemistry	0.94	1.00	1.04	1.04	1.06
Physics	0.61	0.66	0.68	0.69	0.70
Earth and space science	0.58	0.63	0.60	0.63	0.62
Engineering and technology	0.66	0.72	0.82	0.84	0.81
Mathematics	0.44	0.55	0.58	0.66	0.71

(1) A citation ratio of 1.00 reflects no over- or under-citing of Canadian S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of Canadian papers produced for that year.

(2) International citations include citations made to Canadian-authored papers by non-Canadian-authored papers.

Source: Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

Appendix

Table 7. Short- and Long-term Impact Indicators, for Selected Countries and Fields

Country	Publication year of citing paper								
	1976	1977	1978	1979	1980	1981	1982	1983	1984
Short-term impact(1) (citations/paper):									
Biology									
U.S.A.	0.61	0.64	0.65	0.65	0.66	0.70	0.65	..	..
U.K.	0.79	0.78	0.78	0.75	0.75	0.73	0.64	..	..
West Germany	0.64	0.69	0.62	0.68	0.69	0.71	0.66	..	..
France	0.43	0.46	0.46	0.49	0.49	0.50	0.48	..	..
U.S.S.R.	0.16	0.16	0.15	0.16	0.14	0.16	0.13	..	..
Japan	0.57	0.58	0.56	0.52	0.54	0.58	0.50	..	..
Canada	0.61	0.62	0.60	0.61	0.58	0.64	0.57	..	..
Physics									
U.S.A.	1.58	1.65	1.64	1.56	1.51	1.64	1.52	..	..
U.K.	1.12	1.13	1.10	1.04	1.04	1.19	1.01	..	..
West Germany	1.17	1.22	1.30	1.27	1.24	1.40	1.27	..	..
France	0.98	0.99	1.05	1.01	0.98	1.10	0.99	..	..
U.S.S.R.	0.32	0.31	0.36	0.29	0.32	0.33	0.28	..	..
Japan	0.76	0.79	0.80	0.80	0.85	0.89	0.82	..	..
Canada	1.00	0.98	1.00	0.96	0.93	1.03	0.96	..	..
Long-term impact(2) (citations/paper):									
Biology									
U.S.A.	0.61	0.67	0.68	0.68	0.67	0.70	0.72	0.71	0.61
U.K.	0.79	0.81	0.85	0.82	0.81	0.80	0.78	0.81	0.67
West Germany	0.64	0.68	0.61	0.63	0.62	0.62	0.64	0.65	0.55
France	0.43	0.47	0.45	0.47	0.45	0.45	0.46	0.47	0.39
U.S.S.R.	0.16	0.17	0.16	0.16	0.14	0.15	0.13	0.13	0.11
Japan	0.57	0.57	0.58	0.54	0.54	0.55	0.51	0.49	0.42
Canada	0.61	0.65	0.63	0.64	0.62	0.65	0.66	0.64	0.54
Physics									
U.S.A.	1.58	1.62	1.56	1.44	1.36	1.40	1.34	1.34	1.10
U.K.	1.12	1.13	1.06	1.02	0.99	1.07	0.98	0.95	0.79
West Germany	1.17	1.21	1.24	1.17	1.08	1.15	1.12	1.11	0.95
France	0.98	0.99	1.00	0.93	0.89	0.94	0.91	0.90	0.77
U.S.S.R.	0.32	0.31	0.34	0.28	0.29	0.29	0.28	0.27	0.21
Japan	0.76	0.79	0.77	0.74	0.75	0.76	0.74	0.71	0.55
Canada	1.01	0.98	0.95	0.89	0.85	0.87	0.84	0.81	0.68

(1) Citations to papers published in current and preceding three years.

(2) Citations to papers published in current and all preceding years, back to 1973.

Source: For short-term impact indicators, **Evaluation of National Research Performance in Basic Research. A Review of Techniques for Evaluating National Performance in Basic Research with Case Studies in Genetics and Solid State Physics**, Advisory Board for the Research Councils, ABRC Science Policy Studies No. 1, London, 1986.

For long-term impact indicators, Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.